# Observation of sustained glow discharges at high vacuum in the NSCL Deflector Test Stand

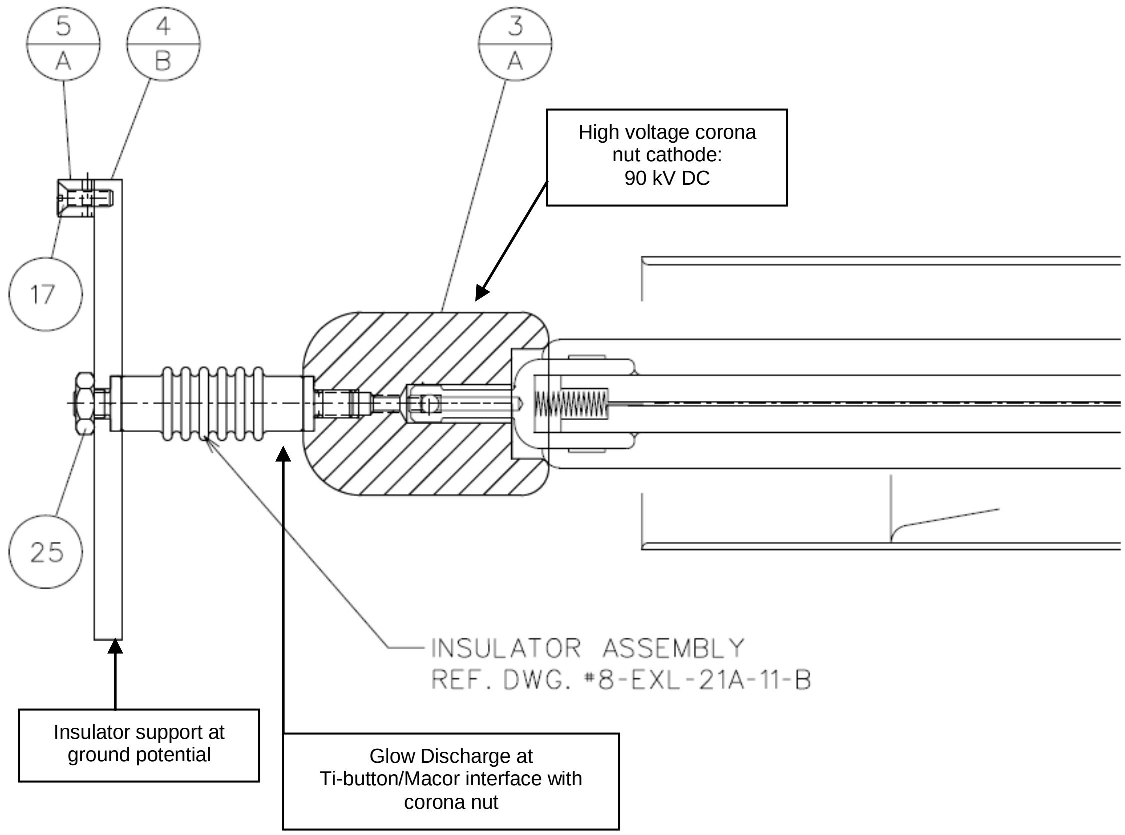


**Figure 1**: Self-sustained [2 or more hours] high voltage breakdown events such as glow discharges were recorded [March 2005] in the deflector test stand [DTS]. The running conditions were 90 kV, better than $10^{-6}$ Torr vacuum, and no added oxygen. The insulator was Macor bonded to Titanium buttons with glass frit [check with Dave Poe for details]. The videos were recorded with a high sensitivity CCD 'bullet' camera. The glow discharge was also monitored with a fiber optic spectrometer to determine what elements were involved in the process. Glow discharge current [i.e. dark current, nominally = 0 μA] = 5 μA, glow discharge voltage = 90 kV, with power dissipated = 0.45 Watts.

Self-sustained glow discharges along with occasional filaments and sparks have been recorded in the Deflector Test Stand [DTS]. In general glow discharges are not expected to occur in a vacuum of $10^{-6}$ Torr since the gas density is tool low to sustain this process. This report documents a self-sustained glow discharge. Also seen were glowing streamers and sparks which momentarily collapsed the glow discharge. A glow discharge started again in the same spot immediately after the spark. The addition of oxygen 'conditioning' gas had no apparent effect on the glow discharge.

The primary purpose of this report is to show that self-sustained glow discharges can occur in high vacuum and not be detected in either voltage or current deviations from normal non-discharge operating conditions since continuous glow discharge current draw and voltage drop are essentially indistinguishable from the noise of the power supply in this case. The sparks occurring at the collapse of the glow discharge may be detectable with a 'spark detector' but continuous filaments associated with the glow discharge would be missed.

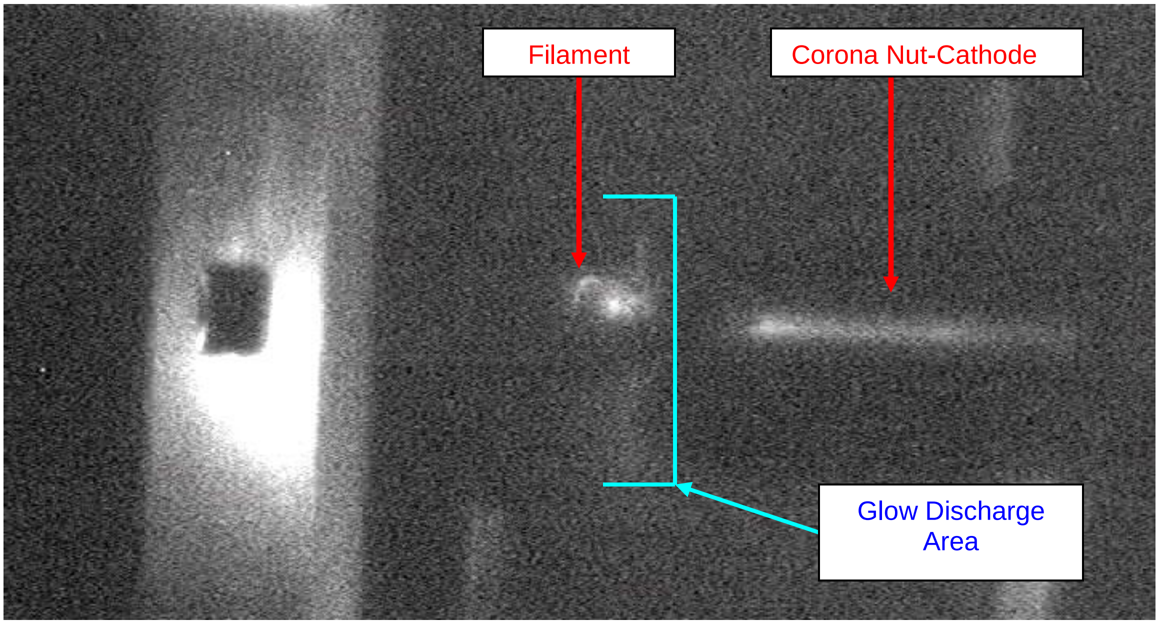


**Figure 2**: Frame from video shows a self-sustained glow discharge with a filament. The running conditions were 90 kV, better than $10^{-6}$ Torr vacuum, and no added oxygen. Glow discharge current [i.e. dark current] ≈ 5 μA, glow discharge voltage ≈ 90 kV, with power dissipated [i.e. glow discharge power] ≈ 0.45 Watts.

The source of the ions in the glow discharge was determined using a fiber optic spectrometer with a 200-850 nm range and +/- 0.6 nm resolution. Aluminum and Sodium were the strongest lines present in the emission line spectra from the glow discharge. The aluminum high voltage corona nut [3/A in figure 1] into which the insulator is mounted is the likely source of the observed Al I lines. The sodium is probably from the glass frit used to braze the titanium button to the Macor body. There is also the remote possibility that the $Al_2O_3$ [16% by weight in Macor or about 8% Al] was reduced to Al metal on or just under the Macor surface. Further surface analysis and narrow field-of-view spectroscopy of the glow discharge may clarify this.

These previously undetected glow discharges and other HV breakdown events are important since they are responsible for the degradation of the insulator by creating conductive surface paths via the deposition of metal ions created by the glow discharges interaction with nearby metal conductors. Since the glow discharge creates ions that get deposited nearby on the insulator, the vacuum level appears to remain unchanged by a volume dilution effect if the atoms or gases liberated in the glow discharge diffuse away from the breakdown region or because the ions are deposited without significant diffusion. These events can be sustained for hours or even days and go undetected by monitoring voltage and current alone.

Since these high voltage events generate enough light to be observed by sensitive CCD cameras [0.05-0.0003 Lux or better] and fiber optic spectrometers, it is possible to have continuous monitoring of many critical high voltage environments and devices and use their output to manage these events to minimize damage. Understanding how these events occur will also provide valuable information for the design of high voltage electrodes and their environments.

Links to videos:
DTS Glow Discharge 1
DTS Glow Discharge 2
DTS Glow Discharge 3

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